Behavioural responses to road pricing: empirical results from a survey among Dutch car owners

Ubbels, B.J.; Verhoef, E.T.

published in
European Transport
2006

European Transport \ Trasporti Europei n. 31 (2005): 101-117

Behavioural responses to road pricing. Empirical results from a survey among Dutch car owners[•]

Barry Ubbels [1*], Erik Verhoef [1]

[1] *Department of Spatial Economics*
Vrije Universiteit Amsterdam
De Boelelaan 1105
1081 HV Amsterdam The Netherlands

Abstract

This paper presents the results from a questionnaire among Dutch car owners. We have analysed the behavioural responses to three different, policy relevant, road pricing measures. Depending on the type of measure and type of trip affected, we find reductions in the number of car trips of, on average, 11%. A flat kilometre charge affects social trips considerably more than commuting trips. However, when policy makers want to affect peak time (commuting) traffic, a time differentiated measure is more appropriate. Slow traffic and trip suppression are most popular alternatives for non-commuting trips. Departure time changes become very attractive for all purposes when the proposed measure varies over time.

Keywords: Road pricing; Behavioural response; Traffic reduction.

1. Introduction

People's responses to transport pricing are not straightforward. Price increases may not necessarily lead to trip suppression, it may also induce travellers to change their modal use or change their departure time, depending on the type of measure. A wide variety of transport pricing measures exists, having different consequences for travel behaviour. Price measures are considered as one of the major tools for policy-makers to influence transport development. The design of measures will generally depend on the objectives set by the government. It is therefore important for authorities to have clear insight into

[•] This research was carried out within the NWO/Connekt VEV project on "A Multidisciplinary Study of Pricing Policies in Transport"; nr. 014-34-351. Financial support is gratefully acknowledged.
[*] Corresponding author: Barry Ubbels (bubbels@feweb.vu.nl)

the responses induced by transport pricing. This response will to a considerable extent depend on the exact design of the pricing scheme (e.g. a yearly tax on car ownership can be expected to affect kilometrage of a given vehicle relatively weakly, compared to a kilometre charge). Equally important, however, is the price sensitivity (often expressed as elasticities by economists) of transport users for the various relevant types of behaviour that together define transport behaviour. People have various possibilities to change transport behaviour, and can be expected to react differently to different pricing schemes.
This paper presents the empirical results from a survey among Dutch car owners towards the behavioural effects of various, policy relevant (at least for the Dutch situation), road pricing measures. Three different type of measures have been evaluated by the respondents. We will analyse the short term behavioural responses in terms of sensitivity and type of change for three different trip purposes.

This paper is organised as follows. Section 2 discusses possible behavioural responses to transport pricing and it gives a brief overview of previous literature results. Section 3 explains the structure of the questionnaire and the type of price measures that have been evaluated by the respondents. Section 4 presents the effectiveness outcomes in terms of car trips that will be replaced by the respondents (including how these trips will be changed). Section 5 concludes.

2. Road transport pricing and behavioural responses

Governments have many different options to intervene in the transport market. Road pricing is one of the possibilities. Current widely implemented price measures in road transport include a tax on vehicle ownership (either at purchase or on an annual basis), parking fees and fuel taxes. Alternative pricing measures include distance related taxes (e.g. a kilometre charge) or particular emission based charges. Also the opposite of charging, viz. subsidising, is a price instrument. Public transport subsidies are for instance often seen as a useful second-best policy in cases where private road transport for some reason cannot be, or is not priced.

Transport users will respond differently to various pricing policies. The possible outcomes (in terms of behavioural responses) of pricing can be the following:

- trip suppression (travel frequency choice);
- departure time choice (and scheduling of daily activities);
- different route choice;
- changes in modal split;
- changes in vehicle occupancy;
- spatial choices related to re-location;
- change in driving style (e.g. speed choice);
- vehicle ownership;
- technology choice;
- changes in destination choice;
- class choice (for public transport).

Depending on the desired aim, policy makers may now decide to make use of a particular price instrument that is likely to steer travel behaviour in a more desired direction. However, it should not be forgotten that the real effect of a price change depends on various factors which makes the effect predictability of a certain measure rather difficult. Factors affecting price sensitivity include among others (VTPI, 2002):

- Type of price change: the different types of pricing measures can have different impacts on travel behaviour.
- Type of trip and traveller: commute trips tend to be less elastic than shopping or recreational trips.
- Quality and price of alternative routes, modes and destinations: price sensitivity tends to increase if alternative routes, modes and destinations are of good quality and affordable. For example, road users tend to be more price sensitive if there is a parallel untolled roadway.
- Time period: transportation elasticities tend to increase over time as consumers have more opportunities to take prices into effect when making long-term decisions (Oum et al., 1997). Dargay and Gately (1997) conclude that about 30% of the response to a price change takes place within 1 year, and that virtually all takes place within 13 years.
- Large and cumulative price changes: extra care should be used when calculating the impacts of large price changes, or when summing the effects of multiple changes, because each subsequent change impacts a different base.

In the next subsection we will briefly discuss some results from the transport economic literature on the behavioural responses to transport pricing (this draws on previous work carried out within the MD-PIT project, see Ubbels and Verhoef, 2003). We pay specific attention to work that analysed the effects of variabilisation in the Netherlands, because we will evaluate similar types of measures for the same country. Variabilisation refers to the situation where present car taxation(independent of car use) is replaced by a kilometre charge.

2.1 Previous literature

A substantial body of empirical economic literature analyses the effects of pricing measures on particular types of behaviour and reports elasticities (a measure of responsiveness of demand to a change in price)[1]. But not only own demand responsiveness can be captured by elasticities, also the use of other modes by changing a particular price can be measured (i.e. cross-price elasticities). Although it is possible to derive elasticities from empirical data (e.g., a before-and-after study of an infrastructure project), normally models are used to derive elasticities. Different types of empirical data are used to derive elasticities. Stated preference data give the reactions as stated by the respondents (e.g. travellers), when confronted with hypothetical alternatives. Revealed preference is based on choices actually made appearing from observed behaviour.

[1] The price elasticity of demand is defined as the percentage change in the quantity demanded divided by the percentage change in price (Stiglitz and Driffill, 2000).

A wide variety of estimates of price elasticities have appeared in economic literature. Among the most widely studied elasticies in transport is the fuel price elasticity. Most estimates of the price elasticity of gasoline consumption are in the range between -0.27 (short run) and -0.71 (long run) (see for an overview Oum and others, 1997 and Goodwin, 1992). Elasticities with respect to vehicle kilometre charges, interesting in the context of this study, are less often reported. There are only a few recent studies which consider the impact of kilometre charges on car use. The European Commission has carried out a major survey on road pricing elasticities (European Commission, 1996). The estimated elasticities consider the effect of road pricing on car use, modal split and route choice. The effects on car use depend on the purpose of the trip: shopping and social trips have the highest, commuter trips the lowest elasticities. The cross-price elasticities range from 0.05 to 0.4 and depend on the transport mode considered (rail or metro) and on the level of charge applied. Geurs and Van Wee (1997) report the results of a variable costs elasticity by using the FACTS model. The effects on car use of a kilometre charge have been simulated by increasing the variable maintenance costs with €cent 5 per kilometre (on a default of €cent 0.5 to 1.5). This results in an elasticity of around –0.20.

Empirical results have been analysed to derive revealed effects and behavioural responses to road pricing in practice (of which effects can also be expressed in elasticities). Despite the fact that road pricing is only rarely implemented, the experiences so far show interesting results. Singapore and Orange County, for instance, are interesting and valuable examples of situations where road pricing is actually implemented. It appears that the effects depend very much on local situations (e.g. public transport availability) and the charging scheme at hand. Road pricing in Singapore, aimed at reducing peak period congestion, was first implemented in 1975 in the form of the Area Licensing Scheme (ALS) and upgraded in 1998 to Electronic Road Pricing (ERP). A method of shoulder pricing is used, which involves increasing the rate in steps every half an hour before the peak and decreasing it after the peak (with charges depending on vehicle type). It appears that traffic is quite sensitive to the road pricing system even though the charges are relatively low, the maximum rate for cars on expressways and to enter the restricted zone is comparable to a 1-hour parking fee in the city (about €1.50) (Olszewiski and Xie, 2005). The elasticity values shown in Table 1 indicate that time of driving will change with time dependent charges. Evening peak traffic flows show the highest demand sensitivity, with an elasticity of -0.32 for cars. The low figures for the morning peak can be explained by arrival time restrictions for commuters, whereas trips to home in the evening can be postponed to avoid the high peak charge.

Table 1: Elasticity of traffic entering the restricted zone by time interval.

Time period	*Cars*	*Other vehicles (motorcycles, taxis, LGV's, HGV's, buses)*	*All vehicles*
7:30-9:30	-0.106	-0.019	-0.069
9:30-15:00	-0.082	-0.080	-0.083
15:30-17:30	-0.123	-0.151	-0.143
17:30-19:00	-0.324	-0.189	-0.265
7:30-19:00	-0.123	-0.106	-0.118

Source: Olszewski and Xie (2005).

The toll charge levied by Orange County depends on the vehicle occupancy and on the level of congestion on the free lanes next to the toll lane. It appeared that the traveller's decision to use the toll lanes is very closely related to hour-by-hour variations in traffic conditions. Results show that a marginal increase in the peak period tariff on the toll facility has only little effect on (increased) travel demand in shoulder peak periods, only very large price changes would induce considerable effects. Moreover, only a few drivers decide to car-pool.

2.1.1 Variabilisation studies in the Netherlands

Since we study the effects of different types of kilometre charges (including measures where revenues are used to compensate for abolition of fixed car taxes), it is interesting to discuss results from so-called variabilisation studies. A few studies have been completed on this issue in the Netherlands, initiated by the increasing policy interest for a kilometre charge.

One of the first studies towards the mobility effects of variabilisation was conducted by MuConsult in 1998 (MuConsult, 1998). A model was used to study the effects of different kilometre charges with the restriction that the revenues for the government remain constant (fixed car taxation was lowered accordingly or abolished). They show that, depending on the level of the charge, implementation may lead to a considerable reduction in total kilometres driven. A kilometre charge of 7 €ct, for instance, leads to a total reduction of 19%. Business traffic is least affected in this scenario (7%), whereas social traffic (23%) and commuting traffic (19%) are most sensitive. Most of these car kilometres is replaced by bicycle use and car-pooling. Effects are less strong when the charge is lower. A charge of 3 €ct is estimated to decrease commuting traffic with 5% and social traffic with 8%. A remarkable prediction of this study is the decrease in car ownership for all scenarios considered; apparently the effect of the increase in the variable charge dominates the effect of lower ownership costs.

A stated preference survey among car owners as well as non-car owners reported in MuConsult (2002) has also analysed the behavioral responses to different types of a kilometre charge with abolition of fixed taxes. We will here discuss their predicted effects of the replacement of the Dutch car ownership tax (the so-called MRB) only, and both the MRB and the tax on car purchase (the so-called BPM). The charges were differentiated according to fuel type, the MRB-only scenario included a charge of 2.4 €ct per kilometre for petrol using cars (with slightly higher charges for cars running on diesel and gas), whereas the MRB+BPM scenario contained a charge of 4.9 €ct (equal levels for other fuel types). In contrast to the earlier MuConsult study, this study predicts an increase in car ownership levels for all alternatives considered. The car stock is assumed to show a stronger growth under the MRB-only scenario compared to the MRB+BPM scenario (2.8% vs. 1.2%). The higher charges in this latter scenario induce relatively more car owners (4.6% vs. 1.3%) to sell their car. The effect on the second-hand market where prices may go down on the car stock has not been included. The results in terms of kilometres indicate a small reduction for the MRB-only scenario of about 0.9% and a somewhat larger effect of 3.4% for the other scenario. These effects include a decrease in kilometres by car owners and an increase of kilometres driven by respondents that indicate to purchase a new car (estimated around 2% for both scenarios). Especially social, shopping and recreational trips will be adjusted, whereas business traffic and kilometres driven for school or educational purposes remain almost unchanged. Commuting trips will be adjusted (about 30%), but less often than the social and shopping trips.

Recently (initiated by a request from the Dutch Minister to search for a new, widely approved, pricing regime), the traffic effects of various road pricing alternatives have once more been investigated using the LMS (Landelijk Model Systeem, a network model developed to forecast traffic flows for the Netherlands) model (Adviesdienst Verkeer en Vervoer, 2005). Among the ten different alternatives that have been evaluated, there were four variabilisation measures. When all fixed taxes (MRB and BPM) are replaced by a kilometre charge (with budget neutrality for the government), the model predicts a decrease in car use (in terms of kilometres) of 11% (compared with the reference situation in 2020). The average charge per kilometre causing these effects was about 5.7 €ct, and depended on fuel type and weight of the car. The level of congestion in 2020 is assumed to be reduced with 40% (in terms of vehicle hours lost). People will change mode (use of train, bus/metro and slow transport increases in terms of kilometres with about 6%) and especially social traffic (29%, in terms of car driven kilometres) and, to a lesser extent, commuting (9%) will be reduced.

Another considered alternative included variabilisation of all car ownership taxes and one quarter of the car purchase taxes. The average kilometre charge is consequently lower (3.4 €ct) than the previous measure, but an additional charge of 0.11 €ct was levied on locations and times with severe congestion. The LMS model outcomes suggest that growth of congestion will be reduced with about 45%. Trip distances will decrease. This effect is limited for commuting trips but larger for social trips. Business traffic (6%) and freight traffic (1%) is predicted to increase, but total traffic demand will decrease (with 10%) due to considerably less commuting (16%) and social kilometres (25%).

The modelling studies predict larger effects on car use than the stated preference study of MuConsult (2002). However, comparing these studies is not straightforward due to differences in the types of measures (e.g. differentiation according to weight versus fuel type) that have been evaluated and underlying assumptions (e.g. the LMS model does not include car ownership effects). Charge levels in the modelling studies have been on average somewhat higher than in the MuConsult 2002 stated preference study, which may be one explanation for the larger effects.

3. Data collection and survey description

3.1 Data collection

The data have been obtained through an (interactive) internet survey among Dutch car owners. The total sample consists of 562 respondents, half of which are car commuters facing congestion on a regular basis, investigated in an earlier questionnaire.[2] These respondents were confronted with three different road pricing measures, and we asked them if and how they expect to change their behaviour when facing these measures. The focus is on the short term responses: the more long term decision of car ownership and car change have been included in the survey, but these will not be discussed in this contribution. The actual data collection was carried out by a specialised firm (NIPO), which has a panel of over 50.000 respondents. The data were collected during three weeks in February 2005.

3.2 Survey

Three different pricing measures will be considered, each in multiple variants. Table 2 shows the various measures that have been developed: 6 different alternatives for measure 1, 2 alternatives for measure 2, and again 6 alternatives of the third measure (a more detailed description of these measures can be found in Appendix 2). The alternatives were divided randomly over the respondents, and each respondent evaluated one alternative of each measure (so three in total). As a result, we obtained at least 88 observations for each alternative of measure 1 (see also Table 4), 282 for measure 2A and 280 for measure 2B, and again about 95 for each alternative of measure 3 (see also Table 8 in Section 4.3).

Table 2: Short description of the road pricing measures presented to the respondents.

Measure	*Variant*
1: Flat kilometre charge with different charge levels and different revenue use	A: 3 €cent, abolition of car ownership taxes B: 6 €cent, abolition of existing car taxation (purchase and ownership) C: 12 €cent, abolition of existing car taxation and investment in new roads D: 3 €cent, revenues used to lower income taxes E: 6 €cent, revenues used to lower income taxes F: 12 €cent, revenues used to lower income taxes
2: Differentiated kilometre charge with different charge levels and different revenue use	A: 2 €cent with multistep (morning and evening) peak time toll on bottlenecks, revenues used to abolish car ownership taxes B: differentiated according to weight of the car, revenues used to abolish existing car taxation
3: Crude peak/off-peak kilometre charge with different charge levels and different revenue use	A: 2 €cent outside peak times and 6 €cent in peak, abolition of car ownership taxes B: 4 €cent outside peak times and 12 €cent in peak, abolition of existing car taxation C: 8 €cent outside peak times and 24 €cent in peak, abolition of existing car taxation and new roads D: 2 €cent outside peak times and 6 €cent in peak, revenues used to lower income taxes E: 4 €cent outside peak times and 12 €cent in peak, revenues used to lower income taxes F: 8 €cent outside peak times and 24 €cent in peak, revenues used to lower income taxes

All descriptions of the measures, as shown to respondents, consisted of two major components: we explain both the structure and level of the charge, and the allocation of the revenues. Furthermore, we provided each respondent individually with an estimation

[2] These respondents have been selected from the first MD-PIT questionnaire of which the results are presented in earlier work (Ubbels and Verhoef, 2005). Note that this first survey was 'over sampled' in the lower income groups so as to obtain a sufficient number of observations.

of the financial consequences of the implementation of the proposed measure (on the basis of self-reported current travel behaviour and car ownership for unchanged behaviour). This estimation depends on the charge level (costs) and on the type of revenue use (benefits). Information on the annual number of kilometres driven, and for some measures also on the type of vehicle (measure 2B) and time of driving (measures 2A and 3) is the input for the cost estimation based on present behaviour. The financial benefits shown to the respondent depend on the type of revenue use. Because it was impossible to give respondents a personal estimation of the financial benefits involved with a recycling via lower income taxation, we only presented the savings for those measures where existing car taxes are abolished[3]. We explained also some practical issues that were meant to prevent various practical considerations from affecting the response: the privacy of car users is guaranteed, electronic equipment registers the toll and the driver can choose freely the payment method (e.g. credit card, bank transfer etc.).

Concerning the representativeness of our sample, we make the following remarks. All respondents own a car, which is used for different trip purposes. This is not necessarily commuting because not all respondents have a job (17.6% is not employed). The educational level of our sample seems relatively high. About 29% of the Dutch car owners has a bachelor or masters degree (based on own calculations of CBS data for 2003), this share is considerably higher in our survey (40%). CBS statistical data also suggests that car ownership increases with income. About 20% of the car owners in this sample has an income below €28,500 (with 9% having no income). Younger people seem to be overrepresented in our survey. About 30% of the car owners in the Netherlands is older than 55, while this share is only 16% in this survey. Most of the respondents are located in the Randstad area (rest west and large cities), the northern part of the Netherlands is only modest represented with 6.4%.

After a concise description of each measure, the respondents were asked whether they would change the number of car trips for three different trip purposes (only in those cases that the respondent indicates that he/she actually makes this type of trip):

- commuting trips (made at least sometimes by 70.7% of the respondents);
- trips to visit people (made at least sometimes by 80.8% of the respondents);
- other type of trips (e.g. shopping, sports activities etc., made at least sometimes by 92.7% of the respondents).

Commuting trips are only made by 70% of the respondents, but the intensity of these trips during a week is relatively higher.

If respondents indicate that they indeed expect to adjust their travel behaviour[4], they were next asked to indicate the share of trips that will be changed, and also how these will be changed. Depending on the type of measure (it makes little sense to ask whether

[3] The benefits from paying less car taxation depend on the type of car the respondents own (i.e., on fuel type and weight). We have estimated averages for nine categories (a combination of three fuel types and three weight categories), for an abolition of annual car ownership taxes (MRB) only and an abolition of all existing car taxation, namely MRB and the fixed purchase tax (BPM).

[4] It is possible that people indicate to make more car trips, in that case we only asked how many extra trips this person would make.

respondents will change departure time when a flat kilometre charge is presented), various possibilities were presented:

- public transport;
- slow transport (walking, bicycle);
- motorised private transport (motorbike, motor);
- carpool (only asked for commuting trips);
- work at home (only asked for commuting trips);
- travel at other times (only when measure is time dependent)[5];
- give up the trip.

In order to analyse the behavioural responses to the proposed pricing measure in a quantitative way, we asked the respondents to indicate for each purpose how many trips they make in a normal week. Because some type of trips are only made once a week, we have asked the respondents to indicate how many trips they will change in a period of 4 weeks (with presenting their total number of trips made for each purpose (4 times the number of trips in a week)). Hence, a respondent indicating that he/she makes 5 commuting trips a week can change 20 trips at most. Next it was asked how these trips will be changed. Respondents could not continue with the survey when the total number of trips to be changed was unequal to the sum of numbers allocated to different alternatives.

Stated preference studies like this one may suffer from various biases, e.g. due to the hypothetical nature of the questions or due to strategic answering. By asking people to indicate very precisely how a certain expected change in total trips was to be accomplished, we hope to have minimised the hypothetical bias as much as reasonable possible. The strategic bias may result in people understating their willingness to change trips, when hoping that ineffectiveness may reduce the chance of the policy to be implemented. Because road pricing was not under public debate at the moment the questionnaire was held, we have good hopes that the strategic bias is not too large.

4. Effectiveness of different pricing regimes

The aim of this survey is to analyse the behavioural responses to realistic and policy relevant road pricing measures[6]. This section focuses on the sensitivity and type of effect of the short term responses to three different road pricing measures presented to the respondents for three different trip purposes (i.e. commuting, social traffic (visits) and other (e.g. shopping)). We have information on the behavioural responses in terms of number of trips that an individual will adjust, and how these will be adjusted. Since we also have an individual estimation of the yearly number of kilometres driven for each trip

[5] Departure time changes have been extensively analysed in an earlier phase of MD-PIT (results obtained from a stated choice experiment).

[6] At this moment policy makers in the Netherlands are seriously considering the implementation of a kilometre charge that replaces current car taxation.

purpose, it is also possible to express changes in terms of kilometres. Information on both outcomes will be presented below.

4.1 Measure 1: kilometre charge (3, 6 and 12 €ct) and different revenue use

The numbers of respondents that indicated they would adjust their car trips when measure 1 becomes reality were 42 (11% of the total number of respondents that makes commuting trips) for commuting, 111 (27%) for visits and 111 (23%) for other trip purposes. After weighting these adjustments by numbers of trips made and by the length of these trips, we can transform these figures into changes in numbers of trips and kilometres. Table 3 shows the aggregated outcomes for all alternatives together; Appendix 2 gives the detailed results for each measure separately.

The numbers vary considerably over the various trip purposes. The proposed kilometre charge is relatively most effective for trips made to visit people, and least effective for commuting trips. This may be explained by the fact that a trip suppression is no serious alternative for commuting trips (only 0.5% of trips to be adjusted will not be made anymore), whereas for other reasons people seriously consider the alternative of not making the trip. Popular alternatives (for all purposes) for car trips include slow transport and public transport. Cycling and walking are in particular an alternative for visits and other trips, apparently these trips are often of short distance. The effectiveness in terms of adjusted number of kilometres is smaller than for numbers of trips, probably people driving relatively less adjust their behaviour.

Table 3: Aggregated outcomes of behavioural responses to measure 1: flat kilometre charge.

	Commuting	Visits	Other
Total number of trips (driven in 4 weeks)	*6800*	*3620*	*7780*
Number of trips adjusted	400 (5.9%)	513 (14.2%)	846 (10.9%)
Of which:			
Public transport	31.8%	17.8%	13.3%
Slow traffic	32.2%	44.6%	64.9%
Motorised	9.5%	8.9%	1.8%
Carpool	19.5%	not relevant	not relevant
Working at home	6.5%	not relevant	not relevant
Not making trip	0.5%	28.6%	19.9%
Number of kilometres adjusted	3.9%	11.6%	9.2%

It is also interesting to consider the relative effectiveness of the various alternatives of measure 1. As expected, a kilometre charge of 12 €ct tends to have more effect than a similar measure with lower charges. Table 4 shows the impact of each alternative for the various purposes. Some results are different than expected: a measure with a higher charge is not always more effective. For instance, measure 1D (with a charge of 3 €ct) seems slightly more effective than measure 1E (6 €ct) for particular trip purposes. Measure 1F induces the strongest trip changes. Alternatives A, B, and C are variabilisation measures, these seem to be less effective than the measures where revenues are used to lower income taxes. The data do not allow us to identify the reason for this difference, but we can speculate. One possible explanation is that we could not inform the respondents on how much they would receive due to the lowered labour tax, while we could make an estimate for the vehicle taxes. If respondents were pessimistic on the net benefit from reduced labour taxes, a perceived stronger income effect might explain the stronger effectiveness. But respondents might also have been less rational. Perhaps they work, implicitly, with predetermined budget allocations over broader groups of consumer products. If so, they may not have realised that they could allocate all benefits from reduced labour taxes to the mobility budget. This is not a very satisfactory explanation, but we can simply not exclude the possibility of irrational responses from at least some of our respondents. As stated, we can only hypothesise about the true reason for this surprising result.

Table 4: Effectiveness related to the alternatives of measure 1.

Measure	*Number of respondents*	***% of total trips adjusted***		
		Commuting	Visits	Other
1A (3 €ct/MRB)	96	0	9.5	13.6
1B (6 €ct/MRB+BPM)	94	5.0	9.4	9.5
1C (12 €ct/MRB+BPM+new roads)	88	11.3	20.3	17.6
1D (3 €ct/income taxes)	101	25.0	15.0	21.2
1E (6 €ct/income taxes)	91	19.7	20.5	16.7
1F (12 €ct/income taxes)	92	39.0	25.3	21.5

4.2 Measure 2: kilometre charge with multistep bottleneck toll (2A) and kilometre charge differentiated according to weight of the vehicle (2B)

The second measure consists of two (very) different alternatives that have in common that the charge is strongly differentiated. The first alternative is a peak period charge combined with a flat kilometre fee, while the measure 2B is differentiated according to weight of the vehicle.

Table 5 shows the behavioural responses for both alternatives separately. Compared to measure 1, we see that one type of response has been added: travel at other times. Because only measure 2A is differentiated according to time, this type of behavioural response is only relevant for that alternative. Changing travel time is very attractive for all trip purposes; people prefer car use at other times over public transport and slow traffic, especially for commuting trips. The respondents will try to avoid the bottlenecks at certain times and are less inclined to give up trips for social or other purposes (relatively to alternative 2B). Note that this alternative has a fine differentiation compared with measure 3, and only applies to certain (bottleneck) locations. Measure 2B seems relatively less effective for commuting trips, only 4% of the total number of commuting trips will be changed. Table 6 confirms this. It shows that measure 2A is responsible for almost three quarter of the adjusted commuting trips. Finally, it appears that slow traffic is an attractive alternative especially for social purposes. These trips probably often have nearby destinations.

Table 5: Behavioural responses to measure 2.

Measure	***Measure 2A***			***Measure 2B***		
Trip purpose	**Commuting**	**Visits**	**Other**	**Commuting**	**Visits**	**Other**
Total number of trips (driven in 4 weeks)	3188	1824	3892	3612	1796	3888
Trips adjusted (% total)	358 (11.2%)	166 (9.1%)	359 (9.2%)	145 (4.0%)	150 (8.4%)	308 (7.9%)
Of which:						
Public transport	22.3%	16.9%	13.1%	13.8%	14.0%	9.7%
Slow traffic	8.9%	29.5%	38.7%	26.2%	46.7%	66.6%
Motorised	2.5%	1.4%	1.7%	38.6%	8.7%	1.0%
Car pooling	10.6%	NR	NR	12.4%	NR	NR
Travel at other times	51.1%	42.2%	38.2%	NR	NR	NR
Working at home	4.2%	NR	NR	6.9%	NR	NR
Not making the trip	0.3%	10.2%	8.3%	2.1%	30.7%	22.7%
Number of kilometres adjusted	11.3%	10.3%	8.2%	2.5%	6.7%	7.4%

NR = not relevant, measure may not be differentiated according to time (2B) or alternative is not relevant for trip purpose.

Table 6: Effectiveness related to the alternatives of measure 2.

	Number of respondents	***% of total trips adjusted***		
		Commuting	Visits	Other
2A: multistep bottleneck toll	282	71.2	52.5	53.8
2B: km charge weight vehicle	280	28.8	47.5	46.2

4.3 Measure 3: peak and off peak kilometre charge with different revenue use

The third measure is a kilometre charge differentiated crudely according to time (peak and off peak only) with different revenue use allocations. Compared to the previous measures, this measure is, in terms of total number adjusted trips (for all purposes), most effective (14,1% versus 9,7% (measure 1) and 7,6% (measure 2). This measure has relatively more impact on commuting trips. The number of trips commuting changed is 1004 (about 15% of the total trips made for commuting reasons), considerably more than 400 (measure 1) and 503 (measure 2). Almost half of the trips that will be adjusted, will be replaced by trips made off-peak (see Table 7, and Appendix 2 for the disaggregated results). Slow traffic is also an attractive alternative, but again only for the non-commuting purposes. The motor or motorbike is not a serious alternative for the respondents, the same holds for carpooling.

The pattern shown in Table 8 is somewhat different from what could be expected. This measure combines different charge levels with different types of revenue use. Alternative C and F have the highest charges, considerably higher than A and D. The estimated benefits of revenue use for alternatives A to C have been presented to the respondents, this has not been done for the alternatives where revenues are used to lower income taxes (D to F). Since higher charges tend to have more effect, alternative C and F may be expected to have more effect than the other alternatives, and B and E again more than A and D. This is not entirely true. Measure 3B, for instance, is considerably less effective than measure 3A for all purposes. The amount of compensation is larger for measure 3B (not only MRB, but also BPM is abolished), but we explained that for both measures the government does not obtain extra revenues (revenue neutrality). A similar pattern is found for measure 3E (compared with 3D), but in this case allocation of revenues was unchanged. Most remarkable is that alternatives with the lowest charge levels (A and D) are even more effective than alternative C and F for certain purposes. The findings for the impact of revenue use (abolition of car taxation vs. income tax reductions) are for most trip purposes equal to the results for measure 1: variabilisation is said to be less effective. Only the outcomes found for measure 3C (visits) and 3A (other purposes) are different in this context, revenues hypothecated to reduce car taxation dominates income tax compensation in terms of effectiveness.

Table 7: Aggregated outcomes of behavioural responses to measure 3: peak and off peak kilometre charge.

	Commuting	Visits	Other
Total number of trips (driven in 4 weeks)	*6800*	*3620*	*7780*
Number of trips adjusted	930 (15%)	529 (14.6%)	1028 (13.2%)
Of which:			
Public transport	17.6%	13.6%	14.1%
Slow traffic	12.7%	28%	28.9%
Motorised	8.8%	1.7%	1.5%
Carpool	4.5%	not relevant	not relevant
Travel at other times	47.7%	47.8%	47.3%
Working at home	7.9%	not relevant	not relevant
Not making trip	0.6%	8.9%	8.3%
Number of kilometers adjusted	14.6%	13.2%	11.2%

When we look at the effects of the measure for trip purposes, it seems that measure 3C has more effect on social visiting trips than for the other purposes. The reverse holds for the same purpose for measure 3F. Measure 3D tends to be less effective for other trips, while on the other hand measure 3A seems most effective for this type of trips. There seems not much of a difference over trip purposes for the other measures.

Table 8: Effectiveness related to the alternatives of measure 3.

Measure	*Number of respondents*	***% of total trips adjusted***		
		Commuting	Visits	Other
3A: 2/6 €cent (off-peak/peak), MRB	96	16.0	14.2	21.6
3B: 4/12 €cent, MRB+BPM	91	13.8	10.0	12.1
3C: 8/24 €cent, car taxation and new roads	97	15.8	25.9	13.1
3D: 2/6 €cent, income taxes	96	19.0	18.9	14.4
3E: 4/12 €cent, income taxes	94	13.9	14.4	15.7
3F: 8/24 €cent, income taxes	88	21.3	16.6	23.2

5. Concluding remarks

The results indicate that road pricing may have considerable effects, much depends on the design of the measure. In terms of trips adjusted, the effectiveness of the measures is in the range of 6% to 15% for all purposes. The effect in terms of kilometres is somewhat smaller. It is often difficult to compare these results with previous literature because of differences in the measures analysed and the research methods applied (modelling vs. stated preference). The work discussed here probably comes closest to the research by MuConsult (2002), although that study included also respondents not owning a car. The outcomes in terms of kilometres for measure 1A and 1B may be comparable to the results of the MuConsult study. Our results then show stronger effects, which cannot entirely be explained by the fact that we have not included non-car owners.

There are considerable differences between trip purposes, with commuting generally being least sensitive when the charge is time independent. Measures 1 and 2 seem to have less effect on commuting trips, which is a rather usual result (e.g. see previous literature results on elasticities and modelling outcomes). In contrast, measures 3 and 2A have a stronger effect on commuting trips. A common characteristic of both measures is the differentiation according to time. Measure 3 seems to be most effective overall, especially for commuting trips.

Slow transport is a popular alternative for trips to visit people or shopping trips, especially when it concerns a flat kilometre charge. This suggests that people often take the car for short trips that can be easily replaced by walking or cycling. Driving at other times is also a popular alternative, especially for the (car dependent) commuting trips. Commuting trips are hard to suppress (working at home or not making the trip are no serious options for most of the respondents), but there seems to be some flexibility allowing the rescheduling of trips. This is confirmed by the empirical results from Singapore (see Olszewski and Xie, 2005).

The impact of the type of measure is not straightforward. Previous research and common sense suggest that higher kilometre charges have more impact. Our results are somewhat mixed on this issue and are difficult to explain. The effect of revenue use is obvious in most cases, the measures with revenues allocated to lower income taxes have generally more effect. Although not very satisfactory, this may be explained by the perceived financial disincentive. Income reduction may be effective, it may not be very acceptable. Ubbels and Verhoef (2005), for instance, show that income reductions might not be very acceptable, whereas abolition of car taxation is. This suggests a possible trade-off between acceptance and effectiveness, which is relevant to keep in mind.

The decision whether or not to implement a price measure remains a political decision, but one should be aware that the effects depend very much on the type of measure. This work shows that when policy makers want to affect peak time (commuting) traffic a time-differentiated measure seems most appropriate. The kilometre charge with additional peak charge is most effective overall, especially for commuting trips. Governments should be aware that implementation of these (time-dependent) charges most probably lead to driving at other times, especially for commuting trips.

References

Adviesdienst Verkeer en Vervoer, (2005) Verkeerskundige effecten varianten 'Anders Betalen voor Mobiliteit', Rotterdam.

Dargay, J. M. and Gately, D. (1997) "Demand for Transportation Fuels: Imperfect Price-Reversibility?", *Transportation Research* B, 31, 1, pp. 71-82.

European Commission, (1996) *Urban Transport, Pricing and Financing of Urban Transport* (APAS), DG VII, Transport Research, Brussels.

Geurs, K. T. and. van Wee, G. P (1997) "Effecten van prijsbeleid op verkeer en vervoer", *RIVM*, Bilthoven.

Goodwin, P. B., (1992) "Review of New Demand Elasticities With Special Reference to Short and Long Run Effects of Price Changes", *Journal of Transport Economics and Policy*, 26, 2, pp. 155-171.

MuConsult, (1998) *Variabilisatie van de autokosten, final report*, Amersfoort

MuConsult, (2002) *Onderzoek naar de Effecten van Kilometerheffing*, concept Onderzoeksrapport, Amersfoort.

Olszewski, P. and Xie, L. (2005) "Modelling the effects of road pricing on traffic in Singapore", *Transportation Research* A, 39, pp 755-772.

Oum, T. H., Waters II, W. G. and Yong, J. S. (1997) "Concepts of price elasticities of transport demand and recent empirical estimates, an interpretative survey", in: Oum, T. H., Dodgson, J. S., Hensher, D. A., Morrison, S. A., Nash, C. A., Small, K. A., and Waters II, W. G. (eds.), *Transport Economics*, pp. 17-49, Harwood Academic publishers, Amsterdam.

Ubbels, B. and Verhoef, E. T. (2003) "Behavioural responses to road transport pricing: a multidisciplinary perspective", *MD-PIT Working paper* 3, Free University Amsterdam.

Ubbels, B., and Verhoef, E. T. (2005) "Acceptability of Road Pricing and Revenue Use in the Netherlands", paper presented at the *European Transport Conference*, Strasbourg.

VTPI (2002) "Transportation Elasticities; how prices and other factors affect travel behaviour", Victoria Transport Policy Institute, Online TDM Encyclopaedia at http://www.vtpi.org/tdm/tdm11.htm#_Toc18128471, Victoria, Canada.

Appendix 1: Description of measures

Measure	***Alternatives***
1: Flat kilometre charge with different revenue allocations	**A**: 3 €cent, revenues used to abolish car ownership taxes (MRB) **B**: 6 €cent, revenues used to abolish existing car taxation (purchase (BPM) and ownership (MRB)) **C**: 12 €cent, revenues used to abolish existing car taxation and construct new roads **D**: 3 €cent, revenues used to lower income taxes **E**: 6 €cent, revenues used to lower income taxes **F**: 12 €cent, revenues used to lower income taxes
2: Flat kilometre charge with additional bottleneck charge (2A) or differentiated according to weight of the car (2B)	**A**: 2 €cent, additional multistep toll during peak times (morning and evening) on working days at daily bottlenecks: 6:00-7:00 € 0,50, 7:00-7:30 € 1,00, 7:30-8:00 € 1,75, 8:00-8:30 € 2,50, 8:30-9:00 € 1,75, 9:00-9:30 € 1,00, 9:30-10:00 € 0,50. The same structure for the evening peak (16.00-20.00). Revenues used to abolish car ownership taxes (MRB) **B**: Light cars pay 4 €cent per kilometre; middle weight cars pay 6 €cent per kilometre; heavy cars pay 8 €cent per kilometre, revenues used to abolish existing car taxation (MRB and BPM)
3: Peak and off peak kilometre charge and different revenue allocations	**A**: 2 €cent outside peak times and 6 €cent in peak on working days (7.00-9.00 and 17.00-19.00), abolition of car ownership taxes **B**: 4 €cent outside peak times and 12 €cent in peak on working days (7.00-9.00 and 17.00-19.00), abolition of existing car taxation **C**: 8 €cent outside peak times and 24 €cent in peak on working days (7.00-9.00 and 17.00-19.00), abolition of existing car taxation and new roads **D**: 2 €cent outside peak times and 6 €cent in peak on working days (7.00-9.00 and 17.00-19.00), revenues used to lower income taxes **E**: 4 €cent outside peak times and 12 €cent in peak on working days (7.00-9.00 and 17.00-19.00), revenues to lower income taxes **F**: 8 €cent outside peak times and 24 €cent in peak on working days (7.00-9.00 and 17.00-19.00), revenues used to lower income taxes

Appendix 2: Behavioural responses to each alternative of measure 1 and 3

Measure	Measure 1A			Measure 1B			Measure 1C		
Trip purpose	**Commuting**	**Visits**	**Other**	**Commuting**	**Visits**	**Other**	**Commuting**	**Visits**	**Other**
Total number of trips (driven in 4 weeks)	1104	556	1468	1176	652	1176	1084	628	1160
Trips adjusted (% total)	0 (0%)	49 (8.8%)	115 (7.8%)	20 (1.7%)	48 (7.4%)	80 (6.8%)	45 (4.1%)	104 (16.6%)	149 (12.8%)
Of which (%):									
Public transport		30.6%	15.6%	20%	10.4%	6.3%	51.1%	10.6%	14.1%
Non-motorised		38.8%	64.3%	10%	56.3%	77.5%	22.2%	44.2%	60.4%
Motorised		0%	0%	0%	8.3%	2.5%	6.7%	18.3%	6.0%
Car pooling		NR	NR	60%	NR	NR	0%	NR	NR
Working at home		NR	NR	10%	NR	NR	20%	NR	NR
Not making the trip		30.6%	20%	0%	25.0%	17.8%	0%	26.9%	19.5%

Measure	Measure 1D			Measure 1E			Measure 1F		
Trip purpose	**Commuting**	**Visits**	**Other**	**Commuting**	**Visits**	**Other**	**Commuting**	**Visits**	**Other**
Total number of trips (driven in 4 weeks)	1212	592	1408	1176	592	1332	1048	600	1236
Trips adjusted (% total)	100 (8.3%)	77 (13%)	179 (12.7%)	79 (6.7%)	105 (17.7%)	141 (10.6%)	156 (14.9%)	130 (21.7%)	182 (14.7%)
Of which (%):									
Public transport	12.0%	27.3%	14.0%	39.2%	12.4%	9.2%	36.5%	20.9%	17.0%
Non-motorised	55.0%	53.2%	63.7%	30.4%	39.0%	68.8%	24.4%	41.1%	61.5%
Motorised	14.0%	0%	0%	1.3%	11.4%	0.7%	12.8%	8.8%	1.6%
Car pooling	11.0%	NR	NR	24%	NR	NR	23.1%	NR	NR
Working at home	7.0%	NR	NR	5.1%	NR	NR	2.6%	NR	NR
Not making the trip	1.0%	19.5%	22.3%	0%	37.1%	21.3%	0.6%	29.0%	19.8%

NR = not relevant, alternative is not related to trip purpose.

Measure	Measure 3A			Measure 3B			Measure 3C		
Trip purpose	**Commuting**	**Visits**	**Other**	**Commuting**	**Visits**	**Other**	**Commuting**	**Visits**	**Other**
Total number of trips (driven in 4 weeks)	1256	636	1572	1096	500	1160	1168	708	1200
Trips adjusted (% total)	161 (12.8%)	75 (11.8%)	222 (14.1%)	139 (12.7%)	53 (10.6%)	124 (10.7%)	159 (13.6%)	137 (19.3%)	135 (11.3%)
Of which:									
Public transport	2.5%	34.7%	16.2%	21.6%	13.2%	25.8%	28.9%	8.7%	3.7%
Non-motorised	0%	10.7%	23.4%	20.1%	20.8%	23.4%	30.2%	30.6%	29.6%
Motorised	13%	0%	0%	6.5%	0%	0.8%	8.8%	2.9%	1.5%
Car pooling	0%	NR	NR	0%	NR	NR	3.8%	NR	NR
Travel at other times	71.4%	45.3%	56.3%	43.9%	60.4%	46%	20.1%	43.8%	46.7%
Working at home	13.0%	NR	NR	7.9%	NR	NR	8.2%	NR	NR
Not making the trip	0%	9.3%	4.0%	0%	5.7%	4.0%	0%	13.9%	18.5%

NR = not relevant, measure may not be differentiated according to time or variant is not related to trip purpose.

Measure	Measure 3D			Measure 3E			Measure 3F		
Trip purpose	**Commuting**	**Visits**	**Other**	**Commuting**	**Visits**	**Other**	**Commuting**	**Visits**	**Other**
Total number of trips (driven in 4 weeks)	1136	640	1256	1112	524	1224	1032	612	1388
Trips adjusted (% total)	191 (16.8%)	100 (15.6%)	148 (11.9%)	140 (12.6%)	76 (13.9%)	161 (13.2%)	214 (20.7%)	88 (14.4%)	238 (17.2%)
Of which:									
Public transport	23.0%	4%	3.4%	10%	3.9%	8.7%	18.2%	22.7%	22.2%
Non-motorised	7.8%	38%	43.9%	15.7%	25%	32.9%	7.%	34.1%	24.4%
Motorised	0%	2%	2.6%	0%	3.9%	0%	21%	0%	3.8%
Car pooling	8.4%	NR	NR	12.8%	NR	NR	2.3%	NR	NR
Travel at other times	57.1%	52%	46.6%	55%	53.9%	50.3%	39.7%	38.6%	38.2%
Working at home	3.1%	NR	NR	5.7%	NR	NR	9.8%	NR	NR
Not making the trip	0.5%	4%	4%	0.7%	13.1%	8%	1.9%	4.5%	11.3%

NR = not relevant, measure may not be differentiated according to time or alternative is not related to trip purpose.